

Absolute Branching Ratio of Beta-Delayed Gamma-Ray Emission of ^{18}N

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The absolute branching ratio of the beta-delayed gamma-ray emission of ^{18}N was measured, providing absolute normalization of the previous work by Olness *et al.* [J.W. Olness, *et al.*, Nuc. Phys. **A373**, 13 (1982)] who measured the relative branching ratios for the individual gamma-rays. We find the total absolute branching ratio for beta-delayed gamma emission of ^{18}N to be $76.7 \pm 7.2(\text{stat}) \pm 5.8(\text{norm})\%$. A combination of other results suggests a value consistent with our result, but smaller than that calculated by Millener as quoted in Olness *et al.*

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In their comprehensive study of the beta-decay of ^{18}N , Olness *et al.* used a theoretical calculation for their overall normalization [1]. While performing a study of the beta-delayed alpha-particle and gamma-ray emissions of ^{16}N at the National Superconducting Cyclotron Laboratory at Michigan State University [2], we were provided with an opportunity to measure the absolute normalization of ^{18}N from data taken during a short calibration run using a ^{18}N beam.

Ions of ^{18}N were implanted into a stack of four Silicon surface barrier detectors (SSB), respectively 50 μm , 25 μm , 25 μm , and greater than 400 μm thick, with most of the beam stopping in the three thin detectors. The detectors were placed at a 45° angle with respect to the beam, as shown in Fig. 1, to increase their effective thickness by a factor of $\sqrt{2}$. Three collimators were placed upstream; the first was of tantalum, and the second two were of brass. A 120% HPGe gamma-ray detector was placed 17.8 cm away from the center of the stacked detectors. The HPGe detector was shielded from the collimators with 10.2 cm of lead [see Fig. 1], with a 3.8 cm diameter hole to allow the HPGe detector to see the SSB detectors. In front of our collimators we placed an aluminum degrader to slow the ions, permitting them to stop in the detectors.

The secondary beam of ^{18}N ions was provided by the A1200 fragment separator at the National Superconducting Cyclotron Laboratory at Michigan State University. The primary beam was ^{18}O at 80 MeV/u with a Beryllium target. The ^{18}N fragments with an energy of about 42 MeV/u were separated using the A1200 in a momentum-loss achromatic mode providing very good

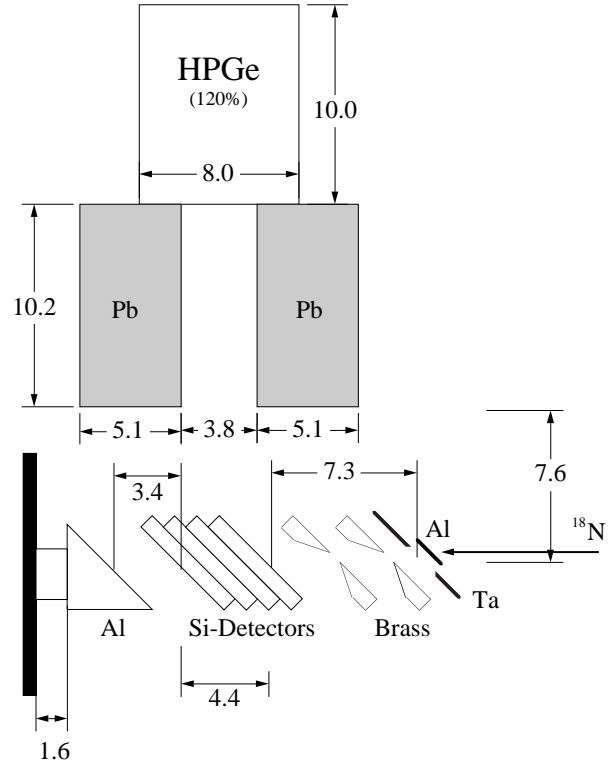


FIG. 1: A schematic diagram of the detector setup drawn to scale. The Alpha detector stack was enclosed in a vacuum chamber. Each detector and the two brass collimators were placed in aluminum frames. All dimensions shown are in centimeters.

mass separation.

The cyclotron was dephased during every other second of the run so that data could be taken with the beam on and with the beam off. Different amplifiers were used during the two phases of the beam cycle, as the beam particles deposited much more energy in the detectors than did the alpha particles.

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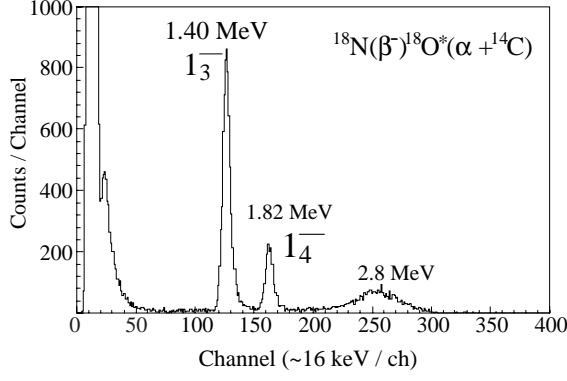


FIG. 2: Measured Beta-Delayed Alpha-Particle Spectrum for ^{18}N .

The absolute efficiency of the HPGe detector was measured by placing a calibrated ^{65}Zn source and a calibrated ^{228}Th source at the position of each alpha detector, each collimator, and the aluminum beam stop. As the detectors were at 45° with respect to the beam and the HPGe detector, the gamma-rays did not pass through the frame of the detector in which the parent ^{18}N nucleus was imbedded. During each calibration run, all items in Fig. 1 were in place except the individual detector replaced by the source. Hence, all absorption of gamma-rays by the setup is included in the efficiency measurements. A calibrated ^{152}Eu was used to determine the energy dependence of the efficiency. The HPGe detector was well shielded with lead from the first two collimators, and the beam, itself, was stopped before the aluminum beam stop.

The yield for alpha particles in the 1.40 MeV peak was measured during the beam-off period as shown in Fig. 2. From Zhao *et al.* [3] the absolute branching ratio for this decay is known to be $6.8 \pm 0.5\%$, which was used for normalization. From Olness *et al.* [1] the 1982 keV transition in ^{18}O has a relative gamma branching ratio of $97.95 \pm 1.96\%$. Olness *et al.* [1] report a calculated total beta-delayed gamma emission branching ratio of $85 \pm 6\%$ leading to an absolute branching ratio of the 1982 keV line of $84 \pm 6\%$. In this work, the absolute branching ratio for the 1982 keV line was measured from its yield relative to the known branching ratios of the beta-delayed alpha-particle decay [2] and the absolute gamma-ray detection efficiency at 1982 keV [see Fig. 3].

The data were corrected for the incomplete stopping of alpha particles within the surface barrier detectors. We measured this effect by plotting the energy in detector 1 versus the energy deposited in detector 2 (and similarly for detectors 2 and 3) as shown in Fig. 4. Here we summed the events lying within the band $E_2 + E_3 = 1.40 \text{ MeV}$ labelled 13^- in Fig. 4. This correction was found to be approximately 2%. The detection of gamma-rays from ^{18}N ions stopped on the collimators or the aluminum beam dump was estimated to be in the range of 1% at 2.6 MeV to unmeasurable at $< 1 \text{ MeV}$. We in-

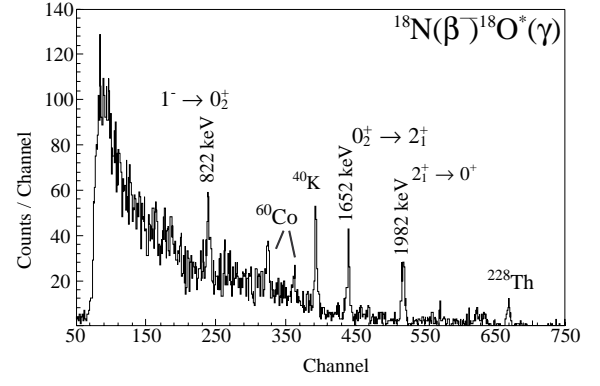


FIG. 3: Measured Beta-Delayed Gamma-Ray Spectrum for ^{18}N .

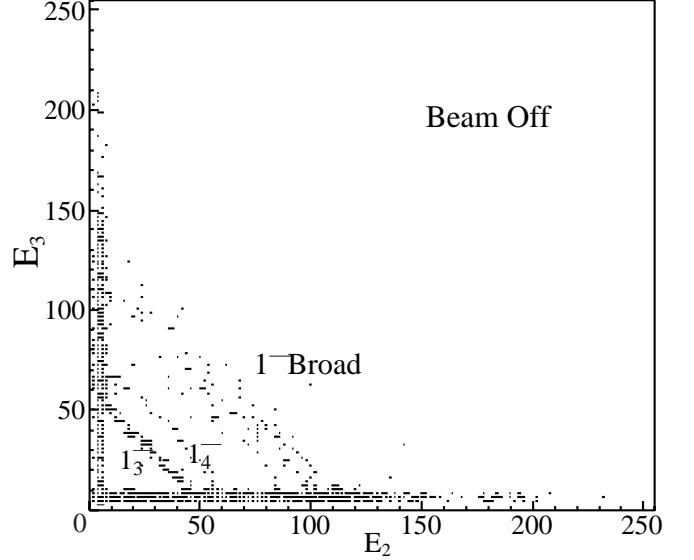


FIG. 4: Energy detected in detector 2 (E_2) vs energy detected in detector 3 (E_3) with beam off.

cluded this uncertainty in the uncertainty of the HPGe efficiency, which is conservatively estimated at 3.3%.

The area of the 1982 keV gamma-ray line, calculated using the LEONE program with a gaussian fit was 118.9 ± 10.9 . The absolute efficiency of the HPGe detector was measured to be $8.16 \pm 0.18 \times 10^{-4}$; thus the total number of 1982 keV gamma-rays emitted during the experiment was $1.46 \pm 0.14 \times 10^5$. The total number of alpha-particles, taking into account all uncertainties listed above, was $1.32 \pm 0.01 \times 10^4$. Combining these with the known branching ratios listed above yields a branching ratio for the 1982 keV line of $75.3 \pm 7.1(\text{stat}) \pm 5.5(\text{norm})\%$, with the normalization uncertainty coming from the uncertainty in the alpha-particle branching ratio. The final branching ratio for all gamma-ray emission is thus $76.7 \pm 7.2(\text{stat}) \pm 5.8(\text{norm})\%$.

The allowed beta-delayed emissions of ^{18}N are beta-delayed alpha-particle, gamma-ray, and neutron emis-

sion. Beta-decay to the ground state of ^{18}O is also predicted to be 2.6% [1]. The total branching ratios for alpha-particle emission are given by Zhao *et al.* [3] as $12.2 \pm 0.6\%$. The branching ratio for higher energy neutron emission is given by Scheller *et al.* [4] as 2%, and the total branching ratio for neutron emission is given by Reeder *et al.* to be $14.3 \pm 2.0\%$ [5]. These combine to a total beta-delayed gamma-ray emission branching ratio of $70.9 \pm 2.1\%$. This value is consistent with our measurement of $76.7 \pm 7.2(\text{stat}) \pm 5.8(\text{norm})\%$, but is smaller than the theoretical value [1] of $85 \pm 6\%$.

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